



## Designing a Conceptual Framework for Estimation and Analysis of Total Ownership Cost



## Background

- **The requirement for affordability assessment via TOC analysis is receiving renewed emphasis for new DoD programs.**
- **Our goal was to design a conceptual framework to enable TOC estimation and analysis for Aerospace and Defense community**
  - Usable by all stakeholders, from the acquisition community, cost estimators and program managers up through the highest levels, such as Congress, DoD financial/budgetary community, and G-8 PA&E.
- **Starting point: Estimation framework well designed for estimates geared toward acquisition community.**

# Definitions

## ■ TOC – Total Ownership Cost

- General<sup>1</sup>:  
Estimate of all direct and indirect costs associated with an asset or acquisition over its entire life cycle
- Defense Acquisition University:  
Elements of a program's life-cycle cost to include business processes cost and infrastructure used in the broadest sense
- “DoD TOC is the sum of all financial resources necessary to organize, equip, train, sustain, and operate military forces sufficient to meet national goals in compliance with all laws, all policies applicable to DoD, all standards in effect for readiness, safety, and quality of life, and all other official measures of performance for DoD and its Components. DoD TOC is comprised of costs to research, develop, acquire, own, operate, and dispose of weapon and support systems, other equipment and real property, the costs to recruit, train, retain, separate and otherwise support military and civilian personnel, and all other costs of business operations of the DoD<sup>2</sup>.”

Notes:

1.Total Ownership Cost Definition Business Dictionary Retrieved 6 May 2010 <http://www.businessdictionary.com/definition/total-cost-of-ownership-TCO.html>

2.Total Ownership Cost Defense Acquisition University Retrieved 6 May 2010 <https://acc.dau.mil/CommunityBrowser.aspx?id=314767#3.1.5>

## Research Method

- **Define use cases**
- **Characterize persona for each stakeholder**
- **Create list of required framework features**
- **Design reporting structure to meet all stakeholders' needs**
- **Design cost model structure that enables TOC estimation**
- **Crosscheck our cost models with standard cost breakdown structures for validating completeness.**

## Use Cases

- **Baseline TOC Estimate**

To establish the basis of the Total Ownership Cost of a proposed program, project, or system for use in contract proposals, trade studies, budget development, and program execution / tracking

- **Affordability Analysis**

To compare the Total Ownership Costs of alternative solutions to achieve a minimum acceptable mission / operational capability at the least cost

- **CAIV Engineering Trade-Off**

To systematically explore the reduction of Total Ownership Costs of Major Weapon or Information Systems by estimating costs associated with changes to the system design

# Stakeholder Personas

- **Personas represent the entire “broader audience” discussed earlier, throughout all 3 use cases.**
- **Step-by-step analysis went through every interaction with the estimation framework.**
- **Personas analyzed include lead system engineers, cost estimators, operations research analysts, contract prog mgrs, gov’t prog mgrs, congressional staffers, G-8 PA&E analysts, etc.**

Title	Roles and Responsibilities	Use Case Tasks
Lead System Engineer	Responsible for the development of the physical architecture of the systems to be costed. Also responsible for the development and documentation of system requirements	<ol style="list-style-type: none"><li>1. Analyze requirements</li><li>2. Develop PBS in conjunction with technical leads</li><li>3. Develop WBS in coordination with program management</li><li>4. Oversee development of system physical architecture</li><li>5. Analyze requirements</li><li>6. Provide technical input to program schedule</li><li>7. Provide input to cost estimators for development of system costs</li><li>8. Oversee design to cost analysis</li></ol>

## Baseline Major Steps, Functions & Features

- **Baseline TOC Estimate Steps: Construct WBS, Assess Cost Model Drivers, Calculate Cost, Validate Model, Map to Reporting Structure.**
- **Example - Step 1: Construct Work Breakdown Structure**

Involved Personas	Input	Process	Output
<b>Cost Estimator, Lead System Engineer</b>	Knowledge of: -Physical Architecture -Matrix Program Functions -O&S structure in context of organization	-Model physical architecture -Add applicable program functions to WBS (Integration, SE, PM, etc.) - Add applicable O&S cost elements to WBS.	Complete WBS modeled in the TruePlanning Estimation Framework.

- **This analysis completed for every step of all 3 use cases.**

# Output Structure – The WBS/CBS/OBS Cube

- **Work Breakdown Structure – How?**

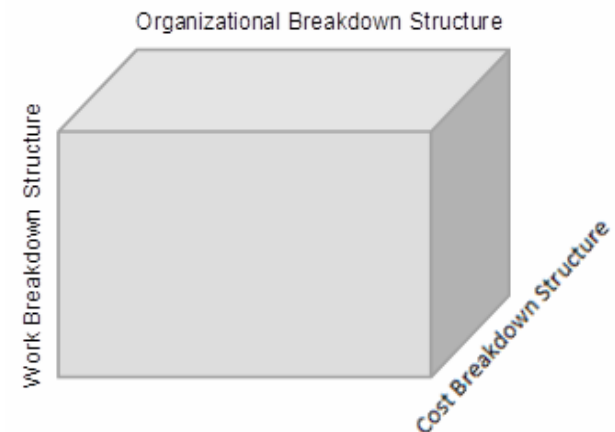
Project broken down into systems, subsystems, components, and work packages (example: Mil-Std-881C)

- **Cost Breakdown Structure – Who Pays?**

Project broken down into useful cost categories, usually budget appropriations.

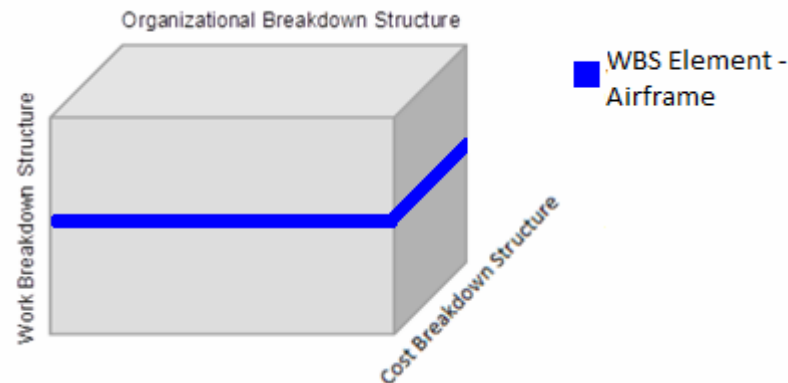
- **Organization Breakdown Structure – Who Does it?**

Project broken down according to organizations involved and their organizational structure. (Congress, PEO, Prime/Sub-contractors and their sites, departments, teams)

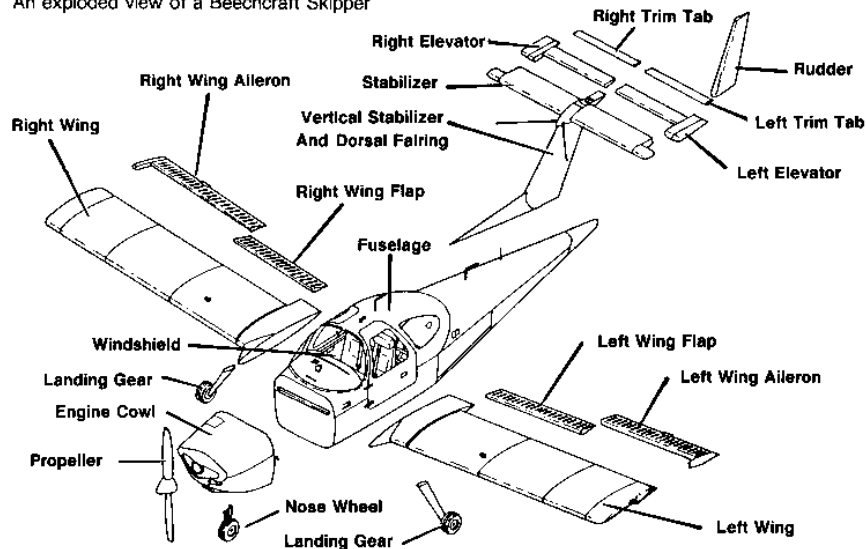




# Slicing and Dicing - The WBS View

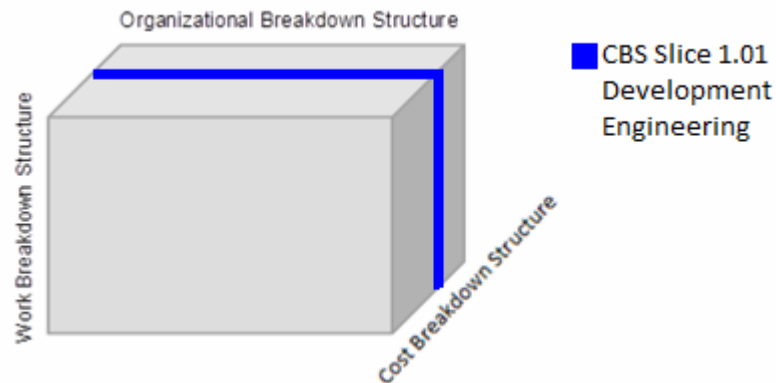


An exploded view of a Beechcraft Skipper



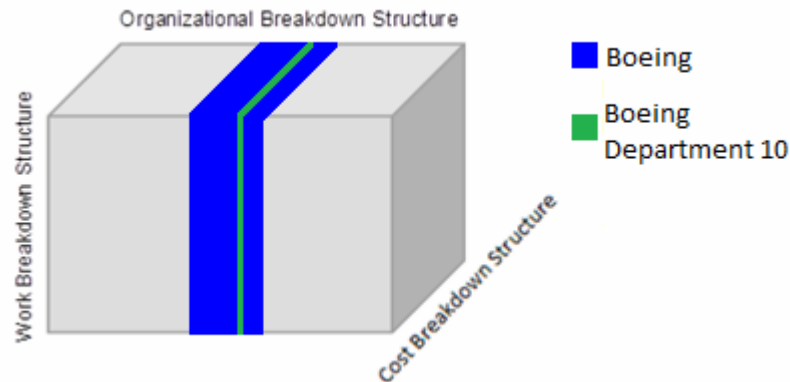
- **Example: “Airframe” WBS Element.**
- **With this view, you can analyze cost estimates and funding for each piece of the airframe, and see which groups in your org. are performing Airframe-specific work.**
- **Quick analysis of alternatives by substituting a WBS element with an alternative solution.**

## Slicing and Dicing – The CBS View



- **Example: CBS Element “Development Engineering” spans multiple organizations, and applies to a variety of components in the WBS.**
- **This view of cost estimate is useful for planning, budgeting and tracking execution.**

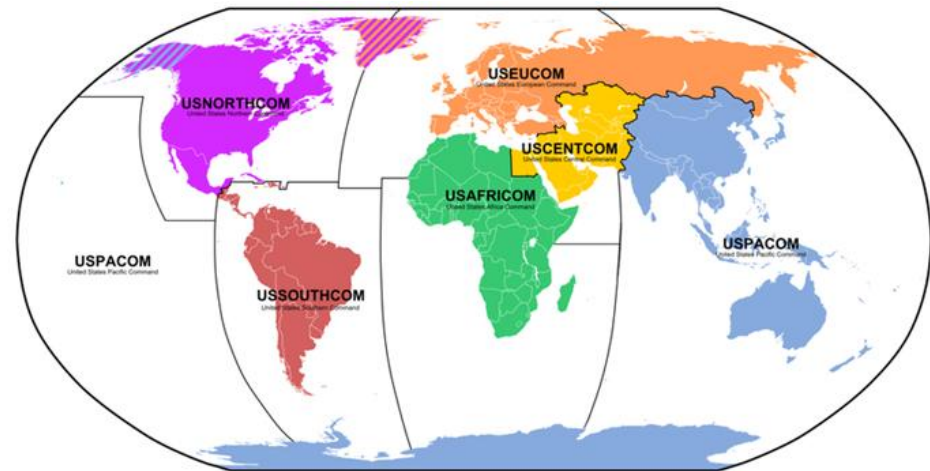
## Slicing and Dicing - The OBS View



- **Example - Boeing is prime contractor, responsible for airframe. Dept. 10 responsible for wing and tail components.**
- **Users can view Dept. 10 slice, and will see all wing and tail deliverables, wing and tail component cost estimates and budgets.**
- **Any “group” can get a customized view with only relevant information.**

# Input Structure – Enterprise Focus

- **Focused on the environment in which the system operates.**
  - Organizational and Operational Factors
  - Theaters
  - Force Structure
- **Aids in Estimating**
  - O&M, MILPERS, MILCON Appropriations
  - System operation within the context of force structure and operational concept.
  - Influence of organizational and theater factors on Maintenance costs.
- **Applications or Uses**
  - Budget Development
  - Program Evaluation
  - Affordability and AoA Analysis
- **Primary Users**
  - Congress
  - G-8 Program Analysis & Evaluation
  - Cost Estimators



# Input Structure – Product Focused

- **Focused on the system being costed.**

- Physical Architecture
- Integration/Assembly
- System Engineering/Project Management

- **Aids in Estimating**

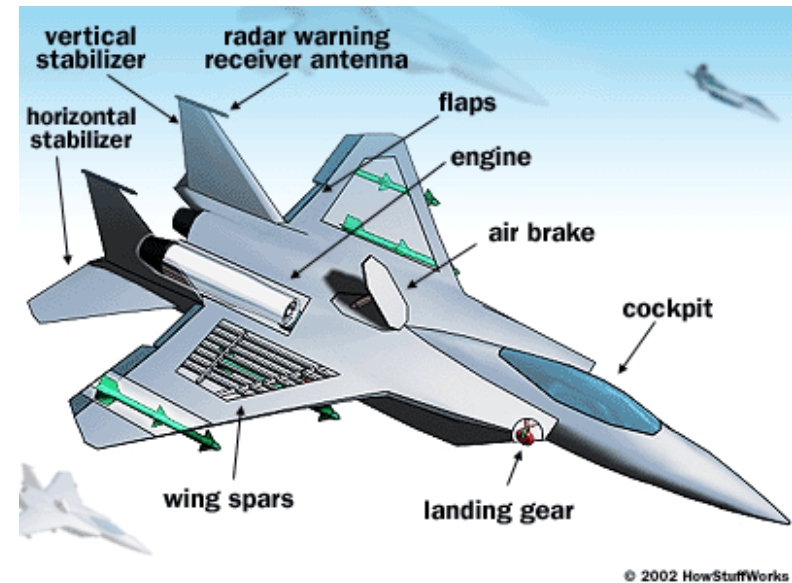
- RDTE / Procurement Appropriations
- Base Cost of Maintenance Action (Failure Rates, Cost of Spares/Repairs)

- **Applications or Uses**

- Proposals
- Program Execution and Management
- Design to Cost
- CAIV for Engineering

- **Primary Users**

- Cost Estimators
- Contractors and Original Equipment Manufacturers
- Program Managers



## Example – Total Cost of Maintenance

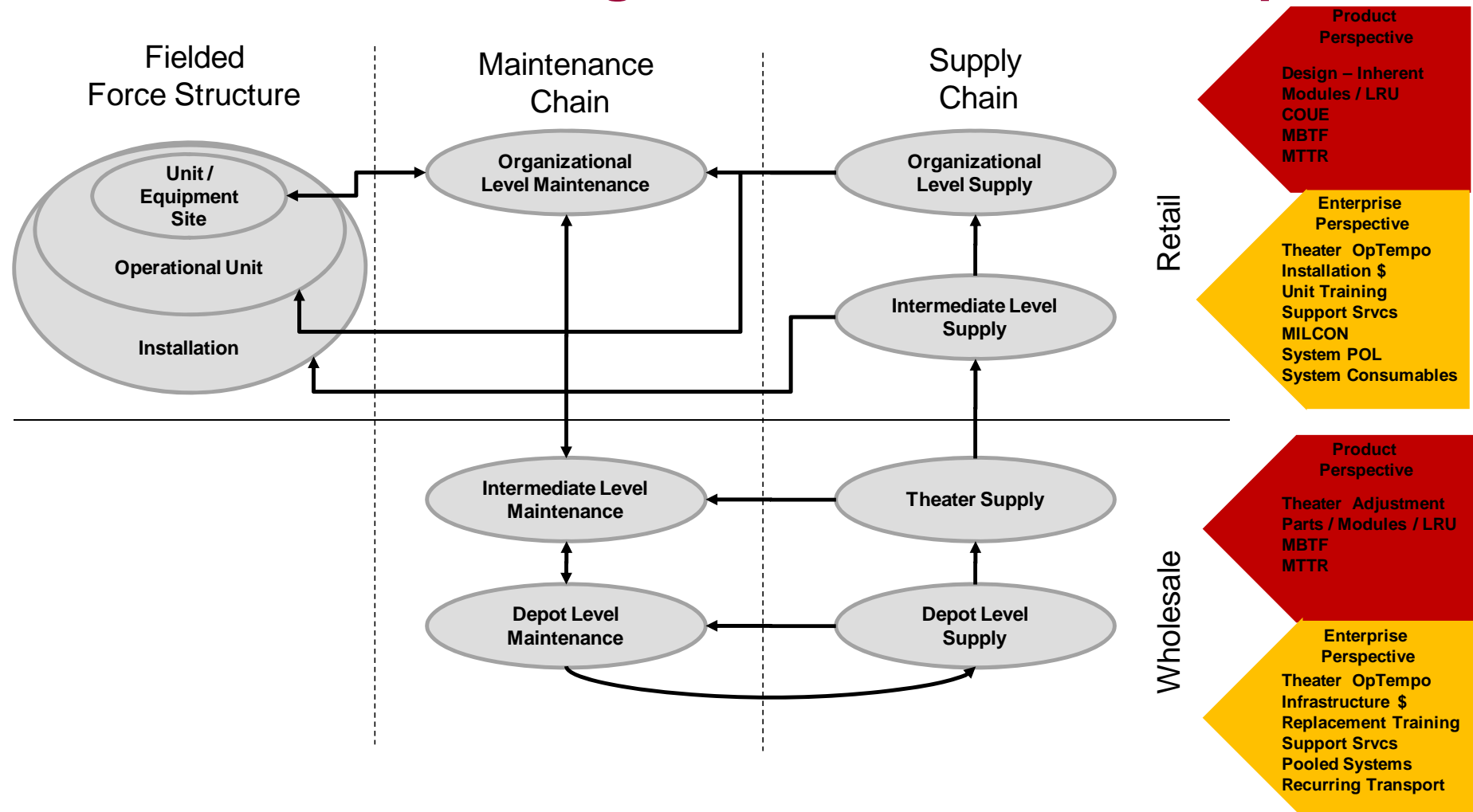
- **Product-Focus**

- Estimates: Cost of a single spare or repair action
- Drivers: MTBF, MTTR, Designation of reparable/replaceable components

- **Enterprise-Focus**

- Estimates: Demand for spares/repairs, Logistics costs
- Drivers: # Supply/Maintenance Points, Shipping costs between facilities, Days of Supply (Stock), Harsh Conditions Adjustment, etc.

# Force Structure – Organizational Relationships



# Ensuring Completeness: CBS Crosswalk

- Comparison of our Cost Model Offerings to standard CBS of Major Organizations:

- Army
- Navy
- NASA
- UK MoD
- CAPE (CAIG)
- NATO

1	2	3	4	B	C	D	N	O	P	Q	R	S	T
						Definition Application Key: Common Definition Multiple Definitions TP Activity Split Between CES Elements Unresolved Conflict New Activity - New Cost Object							
1													
2					<b>TOTAL OWNERSHIP COST</b>	TP Activity Map	Hardware	Hardware COTS	Software	Software COTS	Indirect Support	Maintenance and Modification	Sustaini Suppo
124					<b>Operation &amp; Maintenance (O&amp;M) Funded Elements - Sustainment</b>								
125	5												
126	5.01				Field Maintenance Civilian Labor	Other Unit Level Maintenance Manpow							
127													
128	5.02				System-specific Base Operations	Installation Support					X		
129													
130	5.03				Replenishment Depot Level Repairables (spares)	Replenishment Spares Procurement	X	X				X	
131	5.04				Replenishment Consumables (Repair Parts)	Replenishment Spares Procurement	X	X				X	
132													
133	5.05				Petroleum, Oils & Lubricants (POL)	Operating Materiel							
134													
135													
136	5.06				End Item Supply & Maintenance								
137	5.061				Overhaul (P7M)	Depot Maintenance						X	
138						Operating Equipment Replacement							X
139													
140	5.062				Integrated Materiel Management	Maintenance	X	X					
141						Contractor Support	X	X					X
142													
143	5.063				Supply Depot Support	Support Equipment Maintenance	X	X					X
144						Support Equipment Replacement							X
145													
146	5.064				Industrial Readiness								
147	5.065				Demilitarization								
148	5.07				Transportation	Shipping	X	X					
149						Transportation						X	
150	5.08				Software	Software Maintenance			X	X			
151						Software Modifications or Modernization						X	
152													
153	5.09				System Test & Evaluation, Operational								
154	5.1				System Engineering / Program Management								
155	5.101				Project Management admin (PM Civ)	Sustaining Engineering							X
156													



## Conclusions

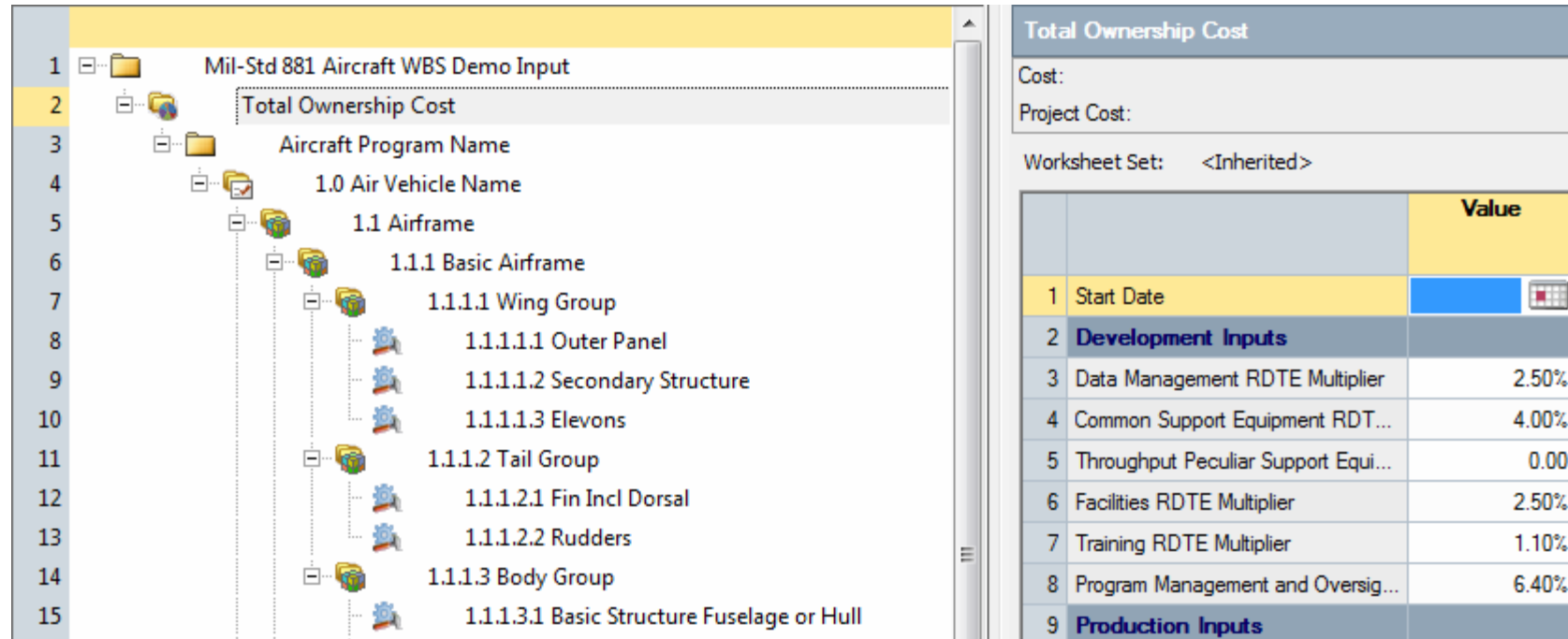
- **Goal: Design a conceptual framework to enable TOC estimation and analysis for a wide variety of stakeholders in A&D community.**
- **Analyzed use cases in terms of user/audience personas, specific tasks and deliverables, and developed list of required framework features.**
- **Gained insight into “cube” data structure, enabling reporting that satisfies all stakeholder requirements.**
- **Analysis of product- vs. enterprise-oriented drivers helped define best cost model structure.**
- **Crosscheck with standardized cost breakdown structures ensured completeness of cost model offerings.**



# Backup Slides

# Total Ownership Cost Model

- Implemented in TruePlanning 2012.
- Gathers data from cost estimate based on WBS, adds environmental enterprise-context, executes algorithms
- Cost Element Complete, minus MILCON and Reserve Funds (AWCF)



The screenshot displays the TruePlanning 2012 interface. On the left, a hierarchical WBS tree is shown for 'Mil-Std 881 Aircraft WBS Demo Input'. The tree structure is as follows:

- Mil-Std 881 Aircraft WBS Demo Input
  - Total Ownership Cost
    - Aircraft Program Name
      - 1.0 Air Vehicle Name
        - 1.1 Airframe
          - 1.1.1 Basic Airframe
            - 1.1.1.1 Wing Group
              - 1.1.1.1.1 Outer Panel
              - 1.1.1.1.2 Secondary Structure
              - 1.1.1.1.3 Elevons
            - 1.1.1.2 Tail Group
              - 1.1.1.2.1 Fin Incl Dorsal
              - 1.1.1.2.2 Rudders
            - 1.1.1.3 Body Group
              - 1.1.1.3.1 Basic Structure Fuselage or Hull

On the right, the 'Total Ownership Cost' table is displayed. It includes a 'Worksheet Set' dropdown set to '<Inherited>' and a table with columns for task ID, task name, and value.

		Value
1	Start Date	
2	<b>Development Inputs</b>	
3	Data Management RDTE Multiplier	2.50%
4	Common Support Equipment RDT...	4.00%
5	Throughput Peculiar Support Equi...	0.00
6	Facilities RDTE Multiplier	2.50%
7	Training RDTE Multiplier	1.10%
8	Program Management and Oversig...	6.40%
9	<b>Production Inputs</b>	

## Issues To Be Resolved

- **Data Analysis – Analysis underway of DoD service's data to develop algorithms for missing cost categories (currently implemented as cost-to-cost relationships or throughput)**
- **Modifying existing physical architecture-based models to easily define LRUs/Modules/Parts and apply maintenance accordingly.**
- **Addressing MILCON**
- **Implementation of data structure to correctly slice and dice the cube**
- **Fully-Burdened Cost of Fuel Model**

# CAIV Major Steps, Functions & Features

## ■ Steps

- Analyze Requirements
- Determine Measures of Effectiveness
- Determine Trade Space
- Identify Cost and Risk Drivers
- Identify Alternative Solutions
- Evaluate TOC
- Interpret Comparative Results
- Document Results and Recommendations

## ■ New Features Required

- Dynamic Business Value Criteria
- TOC Risk Inputs
- Budget or Cost Objective
- Multi-run Results Comparison

# Affordability Major Steps, Functions & Features

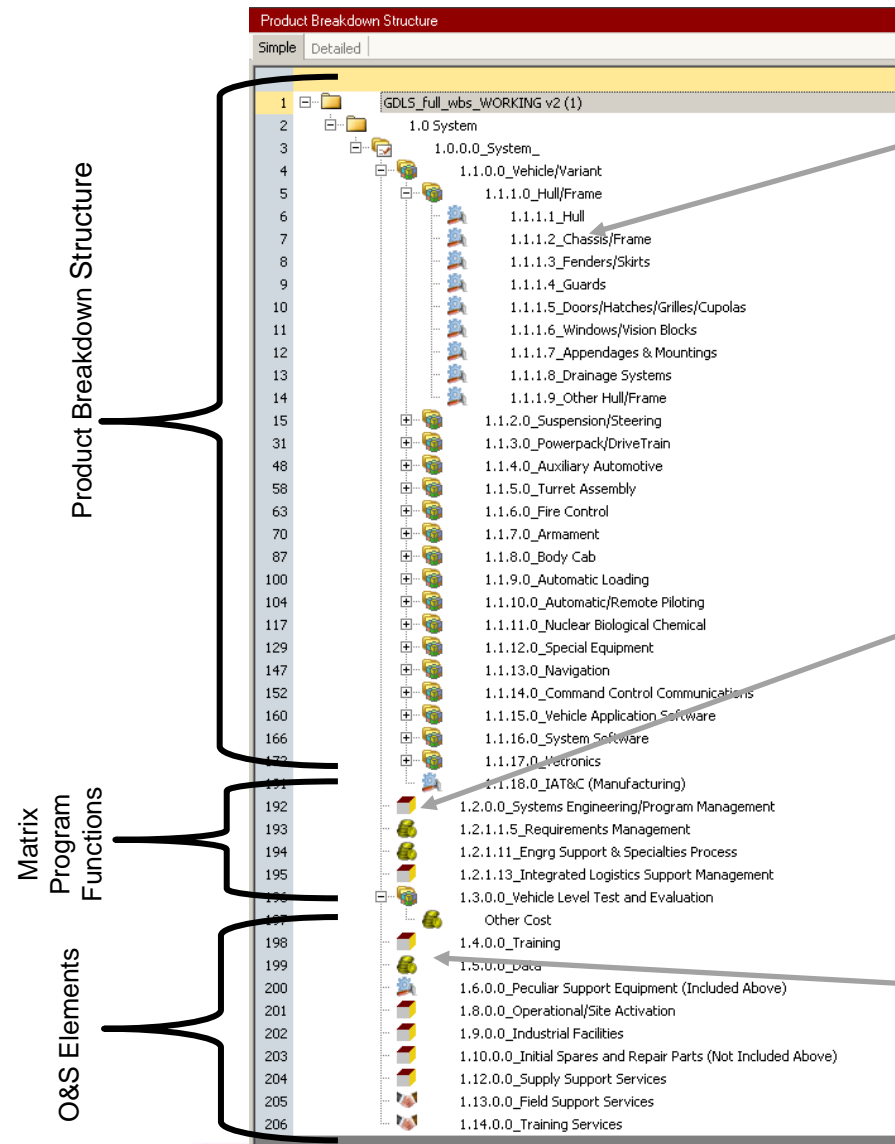
- **Steps**

- Mission Operational Context
- Architecture Development
- Cost, Risk, Performance and Schedule Analysis
- Trade-off Analysis
- Analyze Issues
- Document Results and Recommendations

- **New Features Required**

- Detailed Analysis Output
- Output Manipulation
- Financial Outputs

# WBS Structure (Example Screen Capture)



Traditional costs associated with the Product Breakdown Structure (PBS) such as MTBF for components remain within the PBS hierarchy and component cost object

Cost which really are matrix by function and applied to the entire program across all phases (Dev, Prod, O&S) might be represented as new activities on old cost objects or new activities on new cost objects

O&S might be represented as new activities on old cost objects or new activities on new cost objects



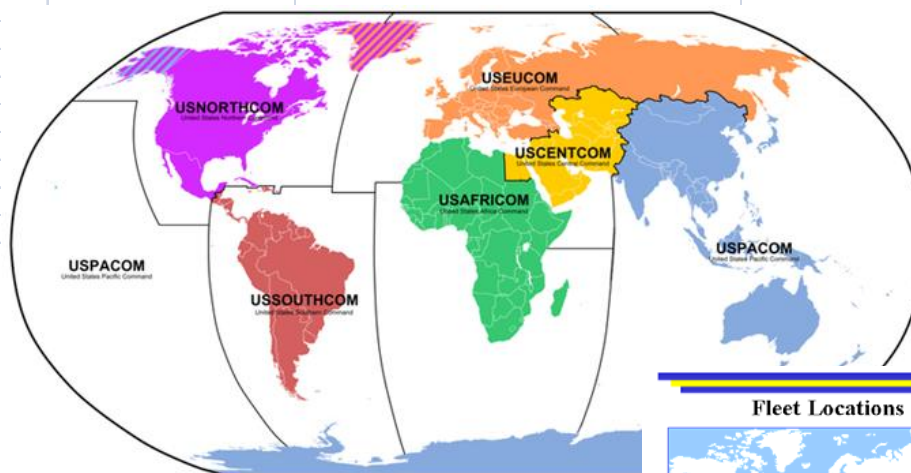
# Operational Perspective

Current US Theaters	ACRONYM	Area Of Resonsponsibility
US Northern Command	NORTHCOM	North America
US Central Command	CENTCOM	Egypt through the Persian Gulf region, into Central Asia; handing over responsibility of Horn of Africa to AFRICOM.
US European Command	EUCOM	Europe, including Turkey, and Israel
US Pacific Command	PACOM	The Asia-Pacific region including Hawaii.
US Southern Command	SOUTHCOM	South, Central America and the surrounding waters
US Africa Command	AFRICOM	Africa excluding Egypt
<b>Non-Theater Commands</b>		
US Special Operations Command	SOCOM	No Geographical Area Responsibility
Us Joint Forces Command	JFOCM	No Geographical Area Responsibility
US Strategic Command	STRATCOM	No Geographical Area Responsibility
US Transportation Command	TRANSCOM	Global mobility of all military assets

## Current British Theaters

British Forces Afghanistan  
British Forces Brunei  
British Forces Cyprus  
British Forces Falkland Islands  
British Forces Gibraltar  
British Forces Germany  
British Forces Iraq

Name	Headquarters
<a href="#">1st Armored Division</a>	<a href="#">Wiesbaden Army Airfield, Germany</a>
<a href="#">1st Cavalry Division</a>	<a href="#">Fort Hood, Texas</a>
<a href="#">1st Infantry Division</a>	<a href="#">Fort Riley, Kansas</a>
<a href="#">2nd Infantry Division</a>	<a href="#">Camp Red Cloud, South Korea</a>
<a href="#">3rd Infantry Division</a>	<a href="#">Fort Stewart, Georgia</a>
<a href="#">4th Infantry Division</a>	<a href="#">Fort Carson, Colorado</a>
<a href="#">10th Mountain Division</a>	<a href="#">Fort Drum, New York</a>
<a href="#">25th Infantry Division</a>	<a href="#">Schofield Barracks, Hawaii</a>
<a href="#">82nd Airborne Division</a>	<a href="#">Fort Bragg, North Carolina</a>
<a href="#">101st Airborne Division</a>	<a href="#">Fort Campbell, Kentucky</a>



## ■ O&S is oriented on two views

- Theater
- Force Structure

## ■ Whereas Development and Production are system product oriented

<a href="#">First Air Force (AFNORTH)</a>		<a href="#">Tyndall Air Force Base, Florida</a>	<a href="#">ACC</a>
<a href="#">Second Air Force</a>		<a href="#">Keesler Air Force Base, Mississippi</a>	<a href="#">AETC</a>
<a href="#">Third Air Force (AFEURO)</a>		<a href="#">Ramstein Air Base, Germany</a>	<a href="#">USAFE</a>
<a href="#">Fourth Air Force</a>		<a href="#">March Air Reserve Base, California</a>	<a href="#">AFRC</a>
<a href="#">Fifth Air Force</a>		<a href="#">Yokota Air Base, Japan</a>	<a href="#">PACAF</a>
<a href="#">Sixth Air Force</a>			<a href="#">6th USAF Emblem (1942-1946) #1</a>
<a href="#">Seventh Air Force (AFKOR)</a>		<a href="#">Osan Air Base, Korea</a>	<a href="#">PACAF</a>
<a href="#">Eighth Air Force (AFSTRAT-GS)</a>		<a href="#">Barksdale Air Force Base, Louisiana</a>	<a href="#">AFSC</a>
<a href="#">Ninth Air Force (AFCENT)</a>		<a href="#">Shaw Air Force Base, South Carolina</a>	<a href="#">ACC</a>
<a href="#">Tenth Air Force</a>		<a href="#">Naval Air Station Joint Reserve Base, Fort Worth, Texas</a>	<a href="#">AFRC</a>

## Definitions

- **Operations:**  
**Operations consists of those actions required to use a system for its intended purpose**
- **Maintenance:**  
**Maintenance consists of corrective or preventative actions taken to ensure equipment or material is in an operational condition**
- **Support:**  
**Support consists of actions, facilities and materiel needed to support a system at the enterprise level**